Exhibit 10 to Complaint
Intellectual Ventures I LLC and Intellectual Ventures II LLC

Example American Count IV Systems and Services
U.S. Patent No. 11,032,000 ("the '000 Patent")

The Accused Systems and Services include without limitation American systems and services that utilize LTE functionality; all past, current, and future systems and services that operate in the same or substantially similar manner as the specifically identified systems and services; and all past, current, and future American systems and services that have the same or substantially similar features as the specifically identified systems and services ("Example American Count IV Systems and Services" or "American Systems and Services").[1]

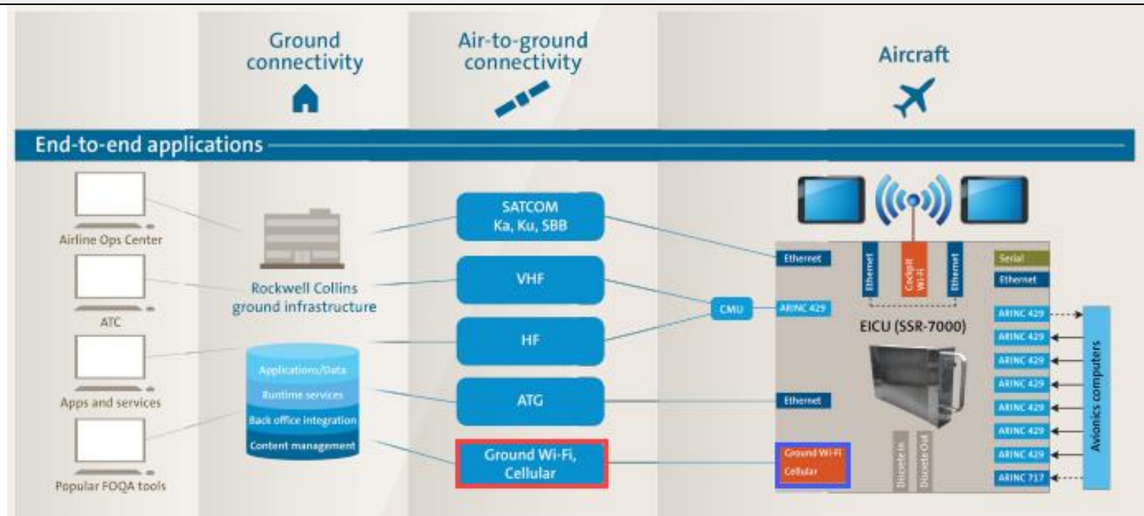
[1] For the avoidance of doubt, Plaintiffs do not accuse licensed systems and services, and to the extent such systems and services has a license to Plaintiffs' patents that covers Defendant's activities. Plaintiffs will provide relevant license agreements for LTE cellular in discovery, to the extent any such license agreements exists and have not already been produced. To the extent any of these licenses are relevant to Defendant's activities, Plaintiffs will meet and confer with Defendant about the impact of such license(s). Once a protective order is entered into the case, Plaintiffs will provide further details.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
[1.pre]. A user equipment (UE) comprising:	To the extent this preamble is limiting, on information and belief, the American Count IV Systems and Services include a user equipment (UE). On information and belief, American airplanes are installed with an Aircraft Interface Device (AID) that provides LTE ground connectivity and acts as a UE in an LTE network. An Aircraft Interface Device (AID) is a hardware system that allows communication between an Electronic Flight Bag (EFB) and an aircraft data bus. AID allows information about the aircraft's position and speed to be obtained from its avionics by registering to the ARINC 717 and ARINC 429 data buses. This device offers certain features, such as automatic update of flight planning and weather information updates on the flight. Source: https://www.fortunebusinessinsights.com/aircraft-interface-device-market-108478.[2] North America held the largest global aircraft interface device market share in the base year. The North American market was valued at USD 13.17 million in 2023. The market's growth is attributed to the rise in aircraft fleet and airlines in the region. The presence of major airlines, such as American Airlines, Delta Airlines, Southwest Airlines, and others will give a boost to the market growth in the region. Source: https://www.fortunebusinessinsights.com/aircraft-interface-device-market-108478. ***Maintenance and safety data transmitted wirelessly from aircraft improves the predictability of operations*** ANNAPOLIS, Md., April 26, 2023 /PRNewswire/ -- Raytheon Technologies' (NYSE: RTX) Collins Aerospace business is partnering with American Airlines to bring the latest in aircraft data management technology to improve the airline's safety, reliability and analytics. Source: https://www.rtx.com/news/news-center/2023/04/26/raytheon-technologies-helping-power-data-driven-decision-making-at-american-airli.

[2] Unless otherwise noted, all sources cited in this document were publicly accessible as of the date of the Complaint.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	American Airlines in the process of installing Collins Aerospace's aircraft interface device (AID) on more than 500 aircraft to speed its data-driven operational decisions. It is installing the device on its Boeing 737NGs, most Airbus A320s and eventually 777s at seven of its locations. Source: https://aviationweek.com/mro/american-airlines-installing-collins-device-aid-predictive-maintenance.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	 Source: https://prd-sc102-cdn.rtx.com/-/media/ca/product-assets/marketing/a/aircraft-interface-device/aircraft-interface-device.pdf?rev=6310f16d4a07421b8b378f63dc9028f4&hash=4EAC48A3962B44A6FBF396B415676C8C.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	 *Rockwell Collins' robust portfolio of information-enabled flight deck router solutions, global communications networks, back-office applications and airline data services will help make a seamless, secure and integrated aviation ecosphere a reality for your airline.* Source: https://www.collinsaerospace.com/-/media/CA/product-assets/marketing/s/secure-server-router-7000/ssr-eicu-7000_ds.pdf?rev=1116c10cc51543dfa1591edcadcb70ba.
[1.a] a receiver and a processor are configured to receive resource allocation information associated with an uplink physical signal, wherein the uplink physical signal and a physical uplink shared channel have different resources;	On information and belief, the American Count IV Systems and Services include a receiver and a processor configured to receive resource allocation information associated with an uplink physical signal, wherein the uplink physical signal and a physical uplink shared channel have different resources. In LTE, a UE is configured to receive radioResourceConfigDedicated IE, which includes PhysicalConfigDedicated IE that further includes SoundingRS-UL-Config IE. This configuration indicates the UE's SRS resources for transmission.

	7.2 RRC protocol states & state transitions
	
	- **RRC_CONNECTED**:
	  - UE has an E-UTRAN-RRC connection;
	  - UE has context in E-UTRAN;
	  - E-UTRAN knows the cell which the UE belongs to;
	  - Network can transmit and/or receive data to/from UE;
	  - Network controlled mobility (handover and inter-RAT cell change order to GERAN with NACC);
	  - Neighbour cell measurements;
	  - At PDCP/RLC/MAC level:
	    - UE can transmit and/or receive data to/from network;
	    - UE monitors control signalling channel for shared data channel to see if any transmission over the shared data channel has been allocated to the UE;
	    - UE also reports channel quality information and feedback information to eNB;
	    - DRX period can be configured according to UE activity level for UE power saving and efficient resource utilization. This is under control of the eNB.
	
	Source: 3GPP TS 36.300 V10.12.0 at 56.

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>
5.3.3.4 Reception of the RRCConnectionSetup by the UE

NOTE: Prior to this, lower layer signalling is used to allocate a C-RNTI. For further details see TS 36.321 [6];

The UE shall:

1> perform the radio resource configuration procedure in accordance with the received radioResourceConfigDedicated and as specified in 5.3.10;

1> if stored, discard the cell reselection priority information provided by the idleModeMobilityControlInfo or inherited from another RAT;

1> stop timer T300;

1> stop timer T302, if running;

1> stop timer T303, if running;

1> stop timer T305, if running;

1> stop timer T306, if running;

1> perform the actions as specified in 5.3.3.7;

1> stop timer T320, if running;

1> enter RRC_CONNECTED;

Source: 3GPP TS 36.331 V10.22.0 at 42.

– RadioResourceConfigDedicated

The IE RadioResourceConfigDedicated is used to setup/modify/release RBs, to modify the MAC main configuration, to modify the SPS configuration and to modify dedicated physical configuration.

<pre>
toEUTRA2
    sps-Config   SPS-Config   OPTIONAL,   -- Need ON
    physicalConfigDedicated   PhysicalConfigDedicated   OPTIONAL,   -- Need ON
    ...,
    [[rlf-TimersAndConstants-r9   RLF-TimersAndConstants-r9   OPTIONAL   -- Need ON
</pre>
</td></tr>
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**

	***RadioResourceConfigDedicated* field descriptions**
	logicalChannelConfig
	For SRBs a choice is used to indicate whether the logical channel configuration is signalled explicitly or set to the default logical channel configuration for SRB1 as specified in 9.2.1.1 or for SRB2 as specified in 9.2.1.2.
	logicalChannelIdentity
	The logical channel identity for both UL and DL.
	mac-MainConfig
	Although the ASN.1 includes a choice that is used to indicate whether the mac-MainConfig is signalled explicitly or set to the default MAC main configuration as specified in 9.2.2, EUTRAN does not apply "*defaultValue*".
	measSubframePatternPCell
	Time domain measurement resource restriction pattern for the PCell measurements (RSRP, RSRQ and the radio link monitoring).
	physicalConfigDedicated
	The default dedicated physical configuration is specified in 9.2.4.
	
	– *PhysicalConfigDedicated*
	
	`tpc-PDCCH-ConfigPUSCH TPC-PDCCH-Config OPTIONAL, -- Need ON`
	`cqi-ReportConfig CQI-ReportConfig OPTIONAL, -- Cond CQI-r8`
	`soundingRS-UL-ConfigDedicated SoundingRS-UL-ConfigDedicated OPTIONAL, -- Need ON`
	`antennaInfo CHOICE {`
	`explicitValue AntennaInfoDedicated,`
	`defaultValue NULL`
	`} OPTIONAL, -- Cond AI-r8`
	`schedulingRequestConfig SchedulingRequestConfig OPTIONAL, -- Need ON`
	
	***SoundingRS-UL-Config* information element**
	
	`SoundingRS-UL-ConfigDedicated ::= CHOICE{`
	`release NULL,`
	`setup SEQUENCE {`
	`srs-Bandwidth ENUMERATED {bw0, bw1, bw2, bw3},`
	`srs-HoppingBandwidth ENUMERATED {hbw0, hbw1, hbw2, hbw3},`
	`freqDomainPosition INTEGER (0..23),`
	`duration BOOLEAN,`
	`srs-ConfigIndex INTEGER (0..1023),`
	`transmissionComb INTEGER (0..1),`
	`cyclicShift ENUMERATED {cs0, cs1, cs2, cs3, cs4, cs5, cs6, cs7}`

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>
<table>
<tr><th>SoundingRS-UL-Config field descriptions</th></tr>
<tr><td>ackNackSRS-SimultaneousTransmission
Parameter: Simultaneous-AN-and-SRS, see TS 36.213 [23, 8.2]. For SCells this field is not applicable and the UE shall ignore the value.</td></tr>
<tr><td>cyclicShift, cyclicShiftAp
Parameter: n_SRS for periodic and aperiodic sounding reference signal transmission respectively. See TS 36.211 [21, 5.5.3.1], where cs0 corresponds to 0 etc.</td></tr>
<tr><td>duration
Parameter: Duration for periodic sounding reference signal transmission. See TS 36.213 [21, 8.2]. FALSE corresponds to "single" and value TRUE to "indefinite".</td></tr>
<tr><td>freqDomainPosition, freqDomainPositionAp
Parameter: n_{RRC} for periodic and aperiodic sounding reference signal transmission respectively, see TS 36.211 [21, 5.5.3.2].</td></tr>
<tr><td>srs-AntennaPort, srs-AntennaPortAp
Indicates the number of antenna ports used for periodic and aperiodic sounding reference signal transmission respectively, see TS 36.211 [21, 5.5.3]. UE shall release srs-AntennaPort if SoundingRS-UL-ConfigDedicated is released.</td></tr>
<tr><td>srs-Bandwidth, srs-BandwidthAp
Parameter: B_{SRS} for periodic and aperiodic sounding reference signal transmission respectively, see TS 36.211 [21, tables 5.5.3.2-1, 5.5.3.2-2, 5.5.3.2-3 and 5.5.3.2-4].</td></tr>
<tr><td>srs-BandwidthConfig
Parameter: SRS Bandwidth Configuration. See TS 36.211, [21, table 5.5.3.2-1, 5.5.3.2-2, 5.5.3.2-3 and 5.5.3.2-4]. Actual configuration depends on UL bandwidth. bw0 corresponds to value 0, bw1 to value 1 and so on.</td></tr>
<tr><td>srs-ConfigApDCI-Format0 / srs-ConfigApDCI-Format1a2b2c / srs-ConfigApDCI-Format4
Parameters indicate the resource configurations for aperiodic sounding reference signal transmissions triggered by DCI formats 0, 1A, 2B, 2C, 4. See TS 36.213 [23, 8.2].</td></tr>
<tr><td>srs-ConfigIndex, srs-ConfigIndexAp
Parameter: I_{SRS} for periodic and aperiodic sounding reference signal transmission respectively. See TS 36.213 [23, table 8.2-1 and table 8.2-2] for periodic and TS 36.213 [23, table 8.2-4 and table 8.2-5] for aperiodic SRS transmission.</td></tr>
<tr><td>srs-HoppingBandwidth
Parameter: SRS hopping bandwidth $b_{hop} \in \{0,1,2,3\}$ for periodic sounding reference signal transmission, see TS 36.211 [21, 5.5.3.2] where hbw0 corresponds to value 0, hbw1 to value 1 and so on.</td></tr>
<tr><td>srs-MaxUpPts
Parameter: srsMaxUpPts, see TS 36.211 [21, 5.5.3.2]. If this field is present, reconfiguration of $m_{\mathrm{SRS},0}^{\max}$ applies for UpPts, otherwise reconfiguration does not apply.</td></tr>
<tr><td>srs-SubframeConfig
Parameter: SRS SubframeConfiguration. See TS 36.211, [21, table 5.5.3.3-1] applies for FDD whereas TS 36.211, [21, table 5.5.3.3-2] applies for TDD. sc0 corresponds to value 0, sc1 to value 1 and so on.</td></tr>
<tr><td>transmissionComb, transmissionCombAp
Parameter: $\bar{k}_{\mathrm{TC}} \in \{0,1\}$ for periodic and aperiodic sounding reference signal transmission respectively, see TS 36.211 [21, 5.5.3.2].</td></tr>
</table>

Source: 3GPP TS 36.331 V10.22.0 at 178, 188, 194.</td></tr>
</table>

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
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<tr><td></td><td>
8.2 UE sounding procedure
A UE shall transmit Sounding Reference Symbol (SRS) on per serving cell SRS resources based on two trigger types:
- trigger type 0: higher layer signalling
- trigger type 1: DCI formats 0/4/1A for FDD and TDD and DCI formats 2B/2C for TDD.
In case both trigger type 0 and trigger type 1 SRS transmissions would occur in the same subframe in the same serving cell, the UE shall only transmit the trigger type 1 SRS transmission.
A UE may be configured with SRS parameters for trigger type 0 and trigger type 1 on each serving cell. The following SRS parameters are serving cell specific and semi-statically configurable by higher layers for trigger type 0 and for trigger type 1.

Transmission comb $\bar{k}_{TC}$, as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
Starting physical resource block assignment n_{RRC} , as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
duration: single or indefinite (until disabled), as defined in [11] for trigger type 0
srs-ConfigIndex I_{SRS} for SRS periodicity T_{SRS} and SRS subframe offset T_{offset} , as defined in Table 8.2-1 and Table 8.2-2 for trigger type 0 and SRS periodicity $T_{SRS,1}$ and SRS subframe offset $T_{offset,1}$, as defined in Table 8.2-4 and Table 8.2-5 trigger type 1
SRS bandwidth B_{SRS} , as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
Frequency hopping bandwidth, b_{hop} , as defined in Section 5.5.3.2 of [3] for trigger type 0
Cyclic shift n_{SRS}^{cs} , as defined in Section 5.5.3.1 of [3] for trigger type 0 and each configuration of trigger type 1

Source: 3GPP TS 36.331 V10.7.0 at 80.
</td></tr>
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**

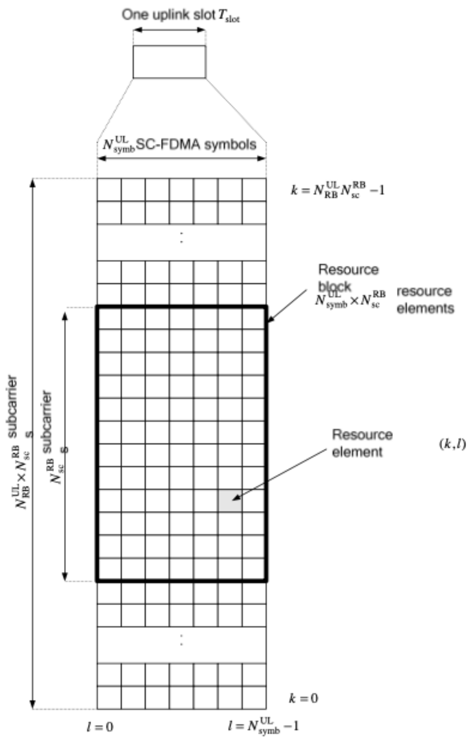
9.2.4 Default physical channel configuration

Parameters

Name	Value	Semantics description	Ver
PDSCH-ConfigDedicated *>p-a*	 dB0		
PUCCH-ConfigDedicated *> tdd-AckNackFeedbackMode* *>ackNackRepetition*	 bundling release	 Only valid for TDD mode	
PUSCH-ConfigDedicated *>betaOffset-ACK-Index* *>betaOffset-RI-Index* *>betaOffset-CQI-Index*	 10 12 15		
UplinkPowerControlDedicated *>p0-UE-PUSCH* *>deltaMCS-Enabled* *>accumulationEnabled* *>p0-UE-PUCCH* *>pSRS-Offset* *> filterCoefficient*	 0 en0 (disabled) TRUE 0 7 fc4		
tpc-pdcch-ConfigPUCCH	release		
tpc-pdcch-ConfigPUSCH	release		
CQI-ReportConfig *> CQI-ReportPeriodic* *> cqi-ReportModeAperiodic* *> nomPDSCH-RS-EPRE-Offset*	 release N/A N/A		
SoundingRS-UL-ConfigDedicated	release		
AntennaInfoDedicated *>transmissionMode* *>codebookSubsetRestriction* *>ue-TransmitAntennaSelection*	 tm1, tm2 N/A release	 If the number of PBCH antenna ports is one, tm1 is used as default; otherwise tm2 is used as default	
SchedulingRequestConfig	release		

Source: 3GPP TS 36.331 V10.22.0 at 263.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	The physical uplink shared channel (PUSCH) is transmitted by the UE with resources elements that are different from SRS resources. **5.2 Slot structure and physical resources** **5.2.1 Resource grid** The transmitted signal in each slot is described by one or several resource grids of $N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{UL}}$ SC-FDMA symbols. The resource grid is illustrated in Figure 5.2.1-1. The quantity $N_{\mathrm{RB}}^{\mathrm{UL}}$ depends on the uplink transmission bandwidth configured in the cell and shall fulfil $N_{\mathrm{RB}}^{\mathrm{min,UL}} \le N_{\mathrm{RB}}^{\mathrm{UL}} \le N_{\mathrm{RB}}^{\mathrm{max,UL}}$ where $N_{\mathrm{RB}}^{\mathrm{min,UL}} = 6$ and $N_{\mathrm{RB}}^{\mathrm{max,UL}} = 110$ are the smallest and largest uplink bandwidths, respectively, supported by the current version of this specification. The set of allowed values for $N_{\mathrm{RB}}^{\mathrm{UL}}$ is given by [7]. The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by the higher layer parameter *UL-CyclicPrefixLength* and is given in Table 5.2.3-1. An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The antenna ports used for transmission of a physical channel or signal depends on the number of antenna ports configured for the physical channel or signal as shown in Table 5.2.1-1. The index $\tilde{p}$ is used throughout Section 5 when a sequential numbering of the antenna ports is necessary.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	 **Figure 5.2.1-1: Uplink resource grid.** **5.2.2 Resource elements** Each element in the resource grid is called a resource element and is uniquely defined by the index pair (k,l) in a slot where $k=0,\ldots,N_{RB}^{UL}N_{sc}^{RB}-1$ and $l=0,\ldots,N_{symb}^{UL}-1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$. When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped. Quantities $a_{k,l}^{(p)}$ corresponding to resource elements not used for transmission of a physical channel or a physical signal in a slot shall be set to zero.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	5.2.3 Resource blocks A physical resource block is defined as $N_{\text{symb}}^{\text{UL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{UL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{\text{symb}}^{\text{UL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain. **Table 5.2.3-1: Resource block parameters.** Configuration / $N_{\text{sc}}^{\text{RB}}$ / $N_{\text{symb}}^{\text{UL}}$ Normal cyclic prefix / 12 / 7 Extended cyclic prefix / 12 / 6 The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k,l) in a slot is given by $n_{\text{PRB}} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$ 5.3 Physical uplink shared channel 5.3.4 Mapping to physical resources

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	For each antenna port p used for transmission of the PUSCH in a subframe the block of complex-valued symbols $z^{(\tilde{p})}(0),...,z^{(\tilde{p})}(M_{\text{symb}}^{\text{ap}}-1)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} in order to conform to the transmit power P_{PUSCH} specified in Section 5.1.1.1 in [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to physical resource blocks on antenna port p and assigned for transmission of PUSCH. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and - not used for transmission of reference signals, and . . . If uplink frequency-hopping is disabled or the resource blocks allocated for PUSCH transmission are not contiguous in frequency, the set of physical resource blocks to be used for transmission is given by $n_{\text{PRB}} = n_{\text{VRB}}$ where n_{VRB} is obtained from the uplink scheduling grant as described in Section 8.1 in [4]. If uplink frequency-hopping with type 1 PUSCH hopping is enabled, the set of physical resource blocks to be used for transmission is given by Section 8.4.1 in [4]. If uplink frequency-hopping with predefined hopping pattern is enabled, the set of physical resource blocks to be used for transmission in slot n_s is given by the scheduling grant together with a predefined pattern according to $$\tilde{n}_{\text{PRB}}(n_s) = \left(\tilde{n}_{\text{VRB}} + f_{\text{hop}}(i)\cdot N_{\text{RB}}^{\text{sb}} + \left(\left(N_{\text{RB}}^{\text{sb}}-1\right) - 2\left(\tilde{n}_{\text{VRB}} \bmod N_{\text{RB}}^{\text{sb}}\right)\right)\cdot f_{\text{m}}(i)\right) \bmod (N_{\text{RB}}^{\text{sb}}\cdot N_{\text{sb}})$$ $$i = \begin{cases} \lfloor n_s/2 \rfloor & \text{inter – subframe hopping} \\ n_s & \text{intra and inter – subframe hopping} \end{cases}$$ $$n_{\text{PRB}}(n_s) = \begin{cases} \tilde{n}_{\text{PRB}}(n_s) & N_{sb}=1 \\ \tilde{n}_{\text{PRB}}(n_s) + \left\lceil N_{\text{RB}}^{\text{HO}}/2 \right\rceil & N_{sb}>1 \end{cases}$$ $$\tilde{n}_{\text{VRB}} = \begin{cases} n_{\text{VRB}} & N_{sb}=1 \\ n_{\text{VRB}} - \left\lceil N_{\text{RB}}^{\text{HO}}/2 \right\rceil & N_{sb}>1 \end{cases}$$ Source: 3GPP TS 36.211 V10.7.0 at 20-21.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	5.4 Physical uplink control channel The physical uplink control channel, PUCCH, carries uplink control information. Simultaneous transmission of PUCCH and PUSCH from the same UE is supported if enabled by higher layers. For frame structure type 2, the PUCCH is not transmitted in the UpPTS field. … The physical resources used for PUCCH depends on two parameters, $N_{\mathrm{RB}}^{(2)}$ and $N_{\mathrm{cs}}^{(1)}$, given by higher layers. The variable $N_{\mathrm{RB}}^{(2)} \geq 0$ denotes the bandwidth in terms of resource blocks that are available for use by PUCCH formats 2/2a/2b transmission in each slot. The variable $N_{\mathrm{cs}}^{(1)}$ denotes the number of cyclic shift used for PUCCH formats 1/1a/1b in a resource block used for a mix of formats 1/1a/1b and 2/2a/2b. The value of $N_{\mathrm{cs}}^{(1)}$ is an integer multiple of $\Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}$ within the range of {0, 1, …, 7}, where $\Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}$ is provided by higher layers. No mixed resource block is present if $N_{\mathrm{cs}}^{(1)} = 0$. At most one resource block in each slot supports a mix of formats 1/1a/1b and 2/2a/2b. Resources used for transmission of PUCCH formats 1/1a/1b, 2/2a/2b and 3 are represented by the non-negative indices $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$, $n_{\mathrm{PUCCH}}^{(2,\tilde{p})} < N_{\mathrm{RB}}^{(2)} N_{\mathrm{sc}}^{\mathrm{RB}} + \left\lceil \frac{N_{\mathrm{cs}}^{(1)}}{8} \right\rceil \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} - N_{\mathrm{cs}}^{(1)} - 2)$, and $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$, respectively. **5.4.1 PUCCH formats 1, 1a and 1b** For PUCCH format 1, information is carried by the presence/absence of transmission of PUCCH from the UE. In the remainder of this section, $d(0) = 1$ shall be assumed for PUCCH format 1. The resource indices within the two resource blocks in the two slots of a subframe to which the PUCCH is mapped are given by $$n'_{\tilde{p}}(n_s) = \begin{cases} n_{\mathrm{PUCCH}}^{(1,\tilde{p})} & \text{if } n_{\mathrm{PUCCH}}^{(1,\tilde{p})} < c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \\ \left(n_{\mathrm{PUCCH}}^{(1,\tilde{p})} - c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}\right) \bmod \left(c \cdot N_{\mathrm{sc}}^{\mathrm{RB}} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}\right) & \text{otherwise} \end{cases}$$

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<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>

5.4.3 Mapping to physical resources

The block of complex-valued symbols $z^{(\tilde{p})}(i)$ shall be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power P_{PUCCH} specified in Section 5.1.2.1 in [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to resource elements. PUCCH uses one resource block in each of the two slots in a subframe. Within the physical resource block used for transmission, the mapping of $z^{(\tilde{p})}(i)$ to resource elements (k,l) on antenna port p and not used for transmission of reference signals shall be in increasing order of first k, then l and finally the slot number, starting with the first slot in the subframe. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1.

Source: 3GPP TS 36.211 V10.7.0 at 12-13, 20-21, 26.

5.5.3 Sounding reference signal

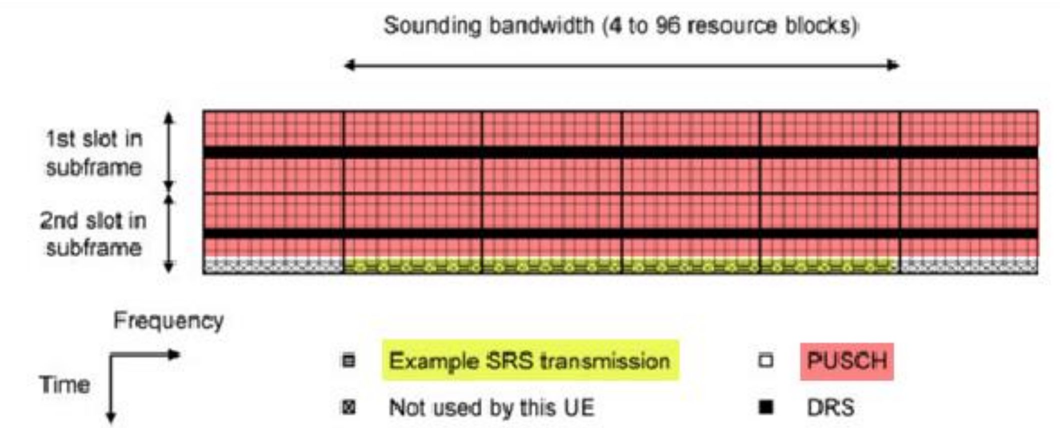
5.5.3.1 Sequence generation

The sounding reference signal sequence $r_{\mathrm{SRS}}^{(\tilde{p})}(n) = r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is defined by Section 5.5.1, where u is the PUCCH sequence-group number defined in Section 5.5.1.3 and v is the base sequence number defined in Section 5.5.1.4. The cyclic shift $\alpha_{\tilde{p}}$ of the sounding reference signal is given as

$$\alpha_{\tilde{p}} = 2\pi \frac{n_{\mathrm{SRS}}^{\mathrm{cs},\tilde{p}}}{8}$$
$$n_{\mathrm{SRS}}^{\mathrm{cs},\tilde{p}} = \left(n_{\mathrm{SRS}}^{\mathrm{cs}} + \frac{8\tilde{p}}{N_{\mathrm{ap}}} \right) \bmod 8 ,$$
$$\tilde{p} \in \{0,1,\ldots,N_{\mathrm{ap}}-1\}$$

where $n_{\mathrm{SRS}}^{\mathrm{cs}} = \{0,1,2,3,4,5,6,7\}$ is configured separately for periodic and each configuration of aperiodic sounding by the higher-layer parameters *cyclicShift* and *cyclicShift-ap*, respectively, for each UE and N_{ap} is the number of antenna ports used for sounding reference signal transmission.

</td></tr>
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	5.5.3.2 Mapping to physical resources For all subframes other than special subframes, the sounding reference signal shall be transmitted in the last symbol of the subframe. Source: 3GPP TS 36.211 V10.7.0 at 35-36. *8.7.2 Sounding Reference Signal* The mobile usually sends the sounding reference signal in the last symbol of the subframe, as shown in Figure 8.11. In TDD mode, it can also send the signal in the  **Figure 8.11** Example resource element mapping for the sounding reference signal, using a normal cyclic prefix. Source: C. Cox, "An Introduction to LTE" (Wiley 2012), § 8.7.2 at 144.
[1.b] a transmitter and the processor are configured to send, over the physical uplink shared channel, data in assigned time intervals;	On information and belief, the American Count IV Systems and Services include a transmitter and the processor configured to send, over the physical uplink shared channel, data in assigned time intervals. The UE transmits data on PUSCH in form of subframes in each TTI interval.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	5.2.2 Uplink shared channel Figure 5.2.2-1 shows the processing structure for the UL-SCH transport channel on one UL cell. Data arrives to the coding unit in the form of a maximum of two transport blocks every transmission time interval (TTI) per UL cell. The following coding steps can be identified for each transport block of an UL cell: Source: 3GPP TS 36.212 V10.9.0 at 22. 5 Physical Layer for E-UTRA Downlink and uplink transmissions are organized into radio frames with 10 ms duration. Two radio frame structures are supported: - Type 1, applicable to FDD, - Type 2, applicable to TDD. Frame structure Type 1 is illustrated in Figure 5.1-1. Each 10 ms radio frame is divided into ten equally sized sub-frames. Each sub-frame consists of two equally sized slots. For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain.  … The physical channels of E-UTRA are: …

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	Physical uplink control channel (PUCCH) - Carries Hybrid ARQ ACK/NAKs in response to downlink transmission; - Carries Scheduling Request (SR); - Carries CQI reports. **Physical uplink shared channel (PUSCH)** - Carries the UL-SCH. Source: 3GPP TS 36.300 V10.12.0 at 38-39. 11.1.2 Uplink Scheduling In the uplink, E-UTRAN can dynamically allocate resources (PRBs and MCS) to UEs at each TTI via the C-RNTI on PDCCH(s). A UE always monitors the PDCCH(s) in order to find possible allocation for uplink transmission when its downlink reception is enabled (activity governed by DRX when configured). When CA is configured, the same C-RNTI applies to all serving cells. Source: 3GPP TS 36.300 V10.12.0 at 93. 5.3 Physical uplink shared channel …

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	5.3.4 Mapping to physical resources For each antenna port p used for transmission of the PUSCH in a subframe the block of complex-valued symbols $z^{(\tilde{p})}(0),...,z^{(\tilde{p})}(M_{\mathrm{symb}}^{\mathrm{ap}}-1)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} in order to conform to the transmit power P_{PUSCH} specified in Section 5.1.1.1 in [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to physical resource blocks on antenna port p and assigned for transmission of PUSCH. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and … If uplink frequency-hopping is disabled or the resource blocks allocated for PUSCH transmission are not contiguous in frequency, the set of physical resource blocks to be used for transmission is given by $n_{\mathrm{PRB}} = n_{\mathrm{VRB}}$ where n_{VRB} is obtained from the uplink scheduling grant as described in Section 8.1 in [4]. If uplink frequency-hopping with type 1 PUSCH hopping is enabled, the set of physical resource blocks to be used for transmission is given by Section 8.4.1 in [4]. If uplink frequency-hopping with predefined hopping pattern is enabled, the set of physical resource blocks to be used for transmission in slot n_s is given by the scheduling grant together with a predefined pattern according to $$\tilde{n}_{\mathrm{PRB}}(n_s) = \left(\tilde{n}_{\mathrm{VRB}} + f_{\mathrm{hop}}(i)\cdot N_{\mathrm{RB}}^{\mathrm{sb}} + \left(\left(N_{\mathrm{RB}}^{\mathrm{sb}}-1\right) - 2\left(\tilde{n}_{\mathrm{VRB}} \bmod N_{\mathrm{RB}}^{\mathrm{sb}}\right)\right)\cdot f_{\mathrm{m}}(i)\right) \bmod (N_{\mathrm{RB}}^{\mathrm{sb}}\cdot N_{\mathrm{sb}})$$ $$i = \begin{cases} \lfloor n_s/2 \rfloor & \text{inter} - \text{subframe hopping} \\ n_s & \text{intra and inter} - \text{subframe hopping} \end{cases}$$ $$n_{\mathrm{PRB}}(n_s) = \begin{cases} \tilde{n}_{\mathrm{PRB}}(n_s) & N_{sb} = 1 \\ \tilde{n}_{\mathrm{PRB}}(n_s) + \left\lceil N_{\mathrm{RB}}^{\mathrm{HO}}/2 \right\rceil & N_{sb} > 1 \end{cases}$$ $$\tilde{n}_{\mathrm{VRB}} = \begin{cases} n_{\mathrm{VRB}} & N_{sb} = 1 \\ n_{\mathrm{VRB}} - \left\lceil N_{\mathrm{RB}}^{\mathrm{HO}}/2 \right\rceil & N_{sb} > 1 \end{cases}$$ Source: 3GPP TS 36.211 V10.7.0 at 20-21.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
[1.c] the transmitter and the processor are further configured, in a time interval that it is not sending information over the physical uplink shared channel, to send the uplink physical signal based on the received resource allocation information, wherein the uplink physical signal is used to determine channel conditions by a base station and in the same time interval that the uplink physical signal is sent, a plurality of UEs transmit uplink physical signals in the same time interval; and	On information and belief, the American Count IV Systems and Services include the transmitter and the processor further configured, in a time interval that it is not sending information over the physical uplink shared channel, to send the uplink physical signal based on the received resource allocation information, wherein the uplink physical signal is used to determine channel conditions by a base station and in the same time interval that the uplink physical signal is sent, a plurality of UEs transmit uplink physical signals in the same time interval. The UE transmits the sounding reference signal in different resource elements and symbols than those used for PUSCH transmission. **8.2 UE sounding procedure** A UE shall transmit Sounding Reference Symbol (SRS) on per serving cell SRS resources based on two trigger types: Source: 3GPP TS 36.213 V10.13.0 at 82.

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>
<h2>5.2 Slot structure and physical resources</h2>
<h3>5.2.1 Resource grid</h3>
The transmitted signal in each slot is described by one or several resource grids of $N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{UL}}$ SC-FDMA symbols. The resource grid is illustrated in Figure 5.2.1-1. The quantity $N_{\mathrm{RB}}^{\mathrm{UL}}$ depends on the uplink transmission bandwidth configured in the cell and shall fulfil
$$N_{\mathrm{RB}}^{\mathrm{min,UL}} \le N_{\mathrm{RB}}^{\mathrm{UL}} \le N_{\mathrm{RB}}^{\mathrm{max,UL}}$$
where $N_{\mathrm{RB}}^{\mathrm{min,UL}} = 6$ and $N_{\mathrm{RB}}^{\mathrm{max,UL}} = 110$ are the smallest and largest uplink bandwidths, respectively, supported by the current version of this specification. The set of allowed values for $N_{\mathrm{RB}}^{\mathrm{UL}}$ is given by [7].
The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by the higher layer parameter UL-CyclicPrefixLength and is given in Table 5.2.3-1.
An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The antenna ports used for transmission of a physical channel or signal depends on the number of antenna ports configured for the physical channel or signal as shown in Table 5.2.1-1. The index $\tilde{p}$ is used throughout Section 5 when a sequential numbering of the antenna ports is necessary.
</td></tr>
</table>

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>

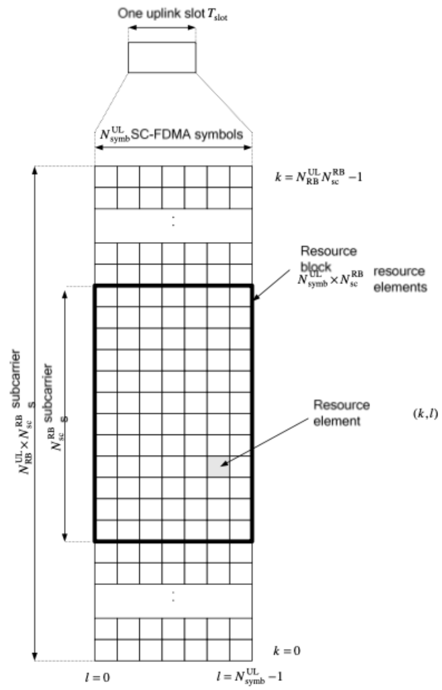


Figure 5.2.1-1: Uplink resource grid.

5.2.2 Resource elements

Each element in the resource grid is called a resource element and is uniquely defined by the index pair (k,l) in a slot where $k = 0,...,N_{RB}^{UL} N_{sc}^{RB} - 1$ and $l = 0,...,N_{symb}^{UL} - 1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$. When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped. Quantities $a_{k,l}^{(p)}$ corresponding to resource elements not used for transmission of a physical channel or a physical signal in a slot shall be set to zero.

</td></tr>
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<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>

5.2.3 Resource blocks

A physical resource block is defined as $N_{\text{symb}}^{\text{UL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{UL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{\text{symb}}^{\text{UL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 5.2.3-1: Resource block parameters.

<table>
<tr><th>Configuration</th><th>$N_{\text{sc}}^{\text{RB}}$</th><th>$N_{\text{symb}}^{\text{UL}}$</th></tr>
<tr><td>Normal cyclic prefix</td><td>12</td><td>7</td></tr>
<tr><td>Extended cyclic prefix</td><td>12</td><td>6</td></tr>
</table>

The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k,l) in a slot is given by

$$n_{\text{PRB}} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$$

5.3 Physical uplink shared channel

5.3.4 Mapping to physical resources

</td></tr>
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	For each antenna port p used for transmission of the PUSCH in a subframe the block of complex-valued symbols $z^{(\tilde{p})}(0),...,z^{(\tilde{p})}(M_{\text{symb}}^{\text{ap}}-1)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} in order to conform to the transmit power P_{PUSCH} specified in Section 5.1.1.1 in [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to physical resource blocks on antenna port p and assigned for transmission of PUSCH. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and - not used for transmission of reference signals, and … If uplink frequency-hopping is disabled or the resource blocks allocated for PUSCH transmission are not contiguous in frequency, the set of physical resource blocks to be used for transmission is given by $n_{\text{PRB}} = n_{\text{VRB}}$ where n_{VRB} is obtained from the uplink scheduling grant as described in Section 8.1 in [4]. If uplink frequency-hopping with type 1 PUSCH hopping is enabled, the set of physical resource blocks to be used for transmission is given by Section 8.4.1 in [4]. If uplink frequency-hopping with predefined hopping pattern is enabled, the set of physical resource blocks to be used for transmission in slot n_s is given by the scheduling grant together with a predefined pattern according to $$\tilde{n}_{\text{PRB}}(n_s) = \left(\tilde{n}_{\text{VRB}} + f_{\text{hop}}(i)\cdot N_{\text{RB}}^{\text{sb}} + \left(\left(N_{\text{RB}}^{\text{sb}}-1\right)-2\left(\tilde{n}_{\text{VRB}} \bmod N_{\text{RB}}^{\text{sb}}\right)\right)\cdot f_{\text{m}}(i)\right)\bmod(N_{\text{RB}}^{\text{sb}}\cdot N_{\text{sb}})$$ $$i = \begin{cases} \lfloor n_s/2 \rfloor & \text{inter – subframe hopping} \\ n_s & \text{intra and inter – subframe hopping} \end{cases}$$ $$n_{\text{PRB}}(n_s) = \begin{cases} \tilde{n}_{\text{PRB}}(n_s) & N_{sb}=1 \\ \tilde{n}_{\text{PRB}}(n_s)+\left\lceil N_{\text{RB}}^{\text{HO}}/2 \right\rceil & N_{sb}>1 \end{cases}$$ $$\tilde{n}_{\text{VRB}} = \begin{cases} n_{\text{VRB}} & N_{sb}=1 \\ n_{\text{VRB}}-\left\lceil N_{\text{RB}}^{\text{HO}}/2 \right\rceil & N_{sb}>1 \end{cases}$$ Source: 3GPP TS 36.211 V10.7.0 at 20-21.

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>

5.4 Physical uplink control channel

The physical uplink control channel, PUCCH, carries uplink control information. Simultaneous transmission of PUCCH and PUSCH from the same UE is supported if enabled by higher layers. For frame structure type 2, the PUCCH is not transmitted in the UpPTS field.

…

The physical resources used for PUCCH depends on two parameters, $N_{\mathrm{RB}}^{(2)}$ and $N_{\mathrm{cs}}^{(1)}$, given by higher layers. The variable $N_{\mathrm{RB}}^{(2)} \geq 0$ denotes the bandwidth in terms of resource blocks that are available for use by PUCCH formats 2/2a/2b transmission in each slot. The variable $N_{\mathrm{cs}}^{(1)}$ denotes the number of cyclic shift used for PUCCH formats 1/1a/1b in a resource block used for a mix of formats 1/1a/1b and 2/2a/2b. The value of $N_{\mathrm{cs}}^{(1)}$ is an integer multiple of $\Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}$ within the range of {0, 1, …, 7}, where $\Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}$ is provided by higher layers. No mixed resource block is present if $N_{\mathrm{cs}}^{(1)} = 0$. At most one resource block in each slot supports a mix of formats 1/1a/1b and 2/2a/2b. Resources used for transmission of PUCCH formats 1/1a/1b, 2/2a/2b and 3 are represented by the non-negative indices $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$, $n_{\mathrm{PUCCH}}^{(2,\tilde{p})} < N_{\mathrm{RB}}^{(2)} N_{\mathrm{sc}}^{\mathrm{RB}} + \left\lceil \frac{N_{\mathrm{cs}}^{(1)}}{8} \right\rceil \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} - N_{\mathrm{cs}}^{(1)} - 2)$, and $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$, respectively.

5.4.1 PUCCH formats 1, 1a and 1b

For PUCCH format 1, information is carried by the presence/absence of transmission of PUCCH from the UE. In the remainder of this section, $d(0) = 1$ shall be assumed for PUCCH format 1.

The resource indices within the two resource blocks in the two slots of a subframe to which the PUCCH is mapped are given by

$$n'_{\tilde{p}}(n_s) = \begin{cases} n_{\mathrm{PUCCH}}^{(1,\tilde{p})} & \text{if } n_{\mathrm{PUCCH}}^{(1,\tilde{p})} < c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \\ \left(n_{\mathrm{PUCCH}}^{(1,\tilde{p})} - c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}\right) \bmod \left(c \cdot N_{\mathrm{sc}}^{\mathrm{RB}} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}\right) & \text{otherwise} \end{cases}$$

</td></tr>
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	5.4.3 Mapping to physical resources The block of complex-valued symbols $z^{(\tilde{p})}(i)$ shall be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power P_{PUCCH} specified in Section 5.1.2.1 in [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to resource elements. PUCCH uses one resource block in each of the two slots in a subframe. Within the physical resource block used for transmission, the mapping of $z^{(\tilde{p})}(i)$ to resource elements (k,l) on antenna port p and not used for transmission of reference signals shall be in increasing order of first k, then l and finally the slot number, starting with the first slot in the subframe. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1. Source: 3GPP TS 36.211 V10.7.0 at 12-13, 20-21, 26. 5.5 Reference signals 5.5.3 Sounding reference signal 5.5.3.2 Mapping to physical resources For all subframes other than special subframes, the sounding reference signal shall be transmitted in the last symbol of the subframe. Source: 3GPP TS 36.211 V10.7.0 at 27, 35, 37. Signaled parameters from the network, for example srs-Bandwidth, are used to characterize the uplink Sounding Reference Signals. 5.5.3 Sounding reference signal

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**

5.5.3.2 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor β_{SRS} in order to conform to the transmit power P_{SRS} specified in Section 5.1.3.1 in [4], and mapped in sequence starting with $r^{(\tilde{p})}_{SRS}(0)$ to resource elements (k,l) on antenna port p according to

$$a^{(p)}_{2k'+k_0^{(p)},l} = \begin{cases} \frac{1}{\sqrt{N_{ap}}}\beta_{SRS}\, r^{(\tilde{p})}_{SRS}(k') & k'=0,1,\ldots,M^{RS}_{sc,b}-1 \\ 0 & \text{otherwise} \end{cases}$$

where N_{ap} is the number of antenna ports used for sounding reference signal transmission and the relation between the index $\tilde{p}$ and the antenna port p is given by Table 5.2.1-1. The set of antenna ports used for sounding reference signal transmission is configured independently for periodic and each configuration of aperiodic sounding. The quantity $k_0^{(p)}$ is the frequency-domain starting position of the sounding reference signal and for $b = B_{SRS}$ and $M^{RS}_{sc,b}$ is the length of the sounding reference signal sequence defined as

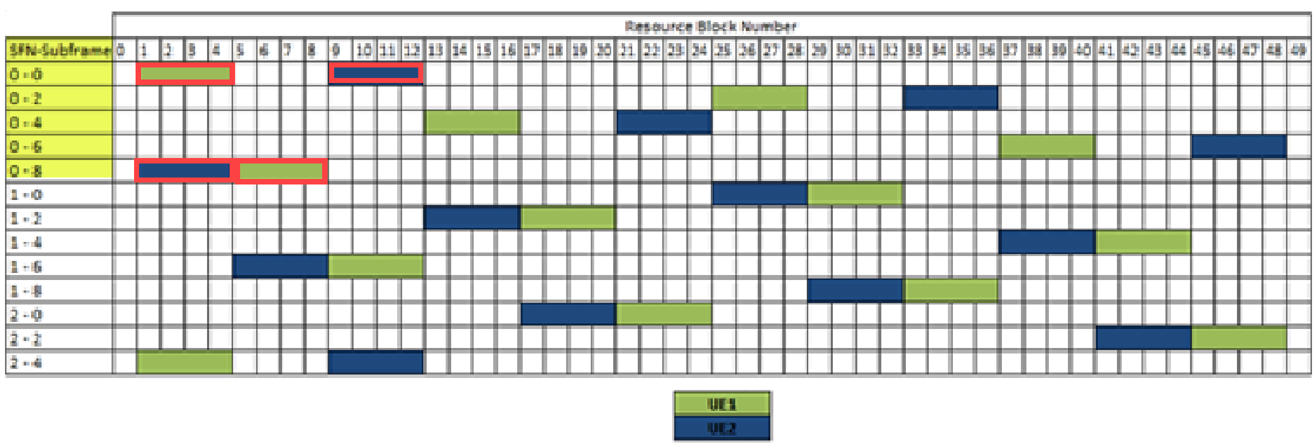
$$M^{RS}_{sc,b} = m_{SRS,b} N^{RB}_{sc}/2$$

where $m_{SRS,b}$ is given by Table 5.5.3.2-1 through Table 5.5.3.2-4 for each uplink bandwidth N^{UL}_{RB}. The cell-specific parameter *srs-BandwidthConfig*, $C_{SRS} \in \{0,1,2,3,4,5,6,7\}$ and the UE-specific parameter *srs-Bandwidth*, $B_{SRS} \in \{0,1,2,3\}$ are given by higher layers. For UpPTS, $m_{SRS,0}$ shall be reconfigured to $m^{max}_{SRS,0} = \max_{c\in C}\{m^{c}_{SRS,0}\} \le (N^{UL}_{RB} - 6N_{RA})$ if this

Table 5.5.3.2-1: $m_{SRS,b}$ and N_b, $b = 0,1,2,3$, values for the uplink bandwidth of $6 \le N^{UL}_{RB} \le 40$.

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{SRS}=0$		SRS-Bandwidth $B_{SRS}=1$		SRS-Bandwidth $B_{SRS}=2$		SRS-Bandwidth $B_{SRS}=3$	
	$m_{SRS,0}$	N_0	$m_{SRS,1}$	N_1	$m_{SRS,2}$	N_2	$m_{SRS,3}$	N_3
0	36	1	12	3	4	3	4	1
1	32	1	16	2	8	2	4	2
2	24	1	4	6	4	1	4	1
3	20	1	4	5	4	1	4	1
4	16	1	4	4	4	1	4	1
5	12	1	4	3	4	1	4	1
6	8	1	4	2	4	1	4	1
7	4	1	4	1	4	1	4	1

Source: 3GPP TS 36.211 V10.7.0 at 35-38.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	The SRS signal is used to estimate the uplink channel conditions. The UE transmits uplink physical signals in the same subframe(s) of a radio frame sent in a single TTI. 7.2.2 **SOUNDING REFERENCE SIGNALS** In contrast, SRS are transmitted on the uplink to allow for the base station to estimate the uplink *channel state* at different frequencies. The channel-state estimates can then, for ***7.2.2.1 Periodic SRS Transmission*** Similar to DM-RS, different phase rotations, also for SRS referred to as "cyclic shifts" in the LTE specifications, can be used to generate different SRS that are orthogonal to each other. By assigning different phase rotations to different devices, multiple SRS can thus be transmitted in parallel in the same subframe, as illustrated by devices #1 and #2 in the upper part of Figure 7.17. However, it is then required that the reference signals span the same frequency range. Source: "4G, LTE-Advanced Pro and The Road to 5G" (Academic Press 3d Ed. 2016) at 185, 187, 188.  Source: https://howltestuffworks.blogspot.com/2014/07/sounding-reference-signal-procedure.html.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
[1.d] the receiver and the processor are further configured to receive, on a physical control channel, control information, wherein the control information is based on the determined channel conditions, wherein physical control channels are transmitted in a same time slot with other physical channels in a plurality of predetermined time slots in a downlink frame, wherein other time slots of the downlink frame do not include a physical control channel, wherein a number of bits sent over the physical control channel is based on a number of fields of control information to be sent to the UE.	On information and belief, the American Count IV Systems and Services include the receiver and the processor further configured to receive, on a physical control channel, control information, wherein the control information is based on the determined channel conditions, wherein physical control channels are transmitted in a same time slot with other physical channels in a plurality of predetermined time slots in a downlink frame, wherein other time slots of the downlink frame do not include a physical control channel, wherein a number of bits sent over the physical control channel is based on a number of fields of control information to be sent to the UE. The UE receives downlink control information (DCI) via PDCCH. The DCI includes uplink scheduling assignments based on the channel conditions measured using the received SRS. 9.1.1 PDCCH Assignment Procedure subclause 6.8.1 in [3], where $N_{CCE,k}$ is the total number of CCEs in the control region of subframe k. The UE shall monitor a set of PDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information in every non-DRX subframe, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats. Source: 3GPP TS 36.213 V10.13.0 at 94.

6.8 Physical downlink control channel

6.8.1 PDCCH formats

The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is N_{REG}. The CCEs available in the system are numbered from 0 to $N_{\mathrm{CCE}}-1$, where $N_{\mathrm{CCE}}=\lfloor N_{\mathrm{REG}}/9 \rfloor$. The PDCCH supports multiple formats as listed in Table 6.8.1-1. A PDCCH consisting of n consecutive CCEs may only start on a CCE fulfilling $i \bmod n = 0$, where i is the CCE number.

Multiple PDCCHs can be transmitted in a subframe.

Table 6.8.1-1: Supported PDCCH formats.

PDCCH format	Number of CCEs	Number of resource-element groups	Number of PDCCH bits
0	1	9	72
1	2	18	144
2	4	36	288
3	8	72	576

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	6.8.2 PDCCH multiplexing and scrambling The block of bits $b^{(i)}(0),...,b^{(i)}(M_{\text{bit}}^{(i)}-1)$ on each of the control channels to be transmitted in a subframe, where $M_{\text{bit}}^{(i)}$ is the number of bits in one subframe to be transmitted on physical downlink control channel number i, shall be multiplexed, resulting in a block of bits $b^{(0)}(0),...,b^{(0)}(M_{\text{bit}}^{(0)}-1),b^{(1)}(0),...,b^{(1)}(M_{\text{bit}}^{(1)}-1),...,b^{(n_{\text{PDCCH}}-1)}(0),...,b^{(n_{\text{PDCCH}}-1)}(M_{\text{bit}}^{(n_{\text{PDCCH}}-1)}-1)$, where n_{PDCCH} is the number of PDCCHs transmitted in the subframe. The block of bits $b^{(0)}(0),...,b^{(0)}(M_{\text{bit}}^{(0)}-1),b^{(1)}(0),...,b^{(1)}(M_{\text{bit}}^{(1)}-1),...,b^{(n_{\text{PDCCH}}-1)}(0),...,b^{(n_{\text{PDCCH}}-1)}(M_{\text{bit}}^{(n_{\text{PDCCH}}-1)}-1)$ shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{tot}}-1)$ according to $$\tilde{b}(i)=\left(b(i)+c(i)\right)\bmod 2$$ where the scrambling sequence $c(i)$ is given by Section 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}}=\lfloor n_s/2\rfloor 2^9+N_{\text{ID}}^{\text{cell}}$ at the start of each subframe. CCE number n corresponds to bits $b(72n),b(72n+1),...,b(72n+71)$. If necessary, <NIL> elements shall be inserted in the block of bits prior to scrambling to ensure that the PDCCHs starts at the CCE positions as described in [4] and to ensure that the length $M_{\text{tot}}=8N_{\text{REG}}\geq\sum_{i=0}^{n_{\text{PDCCH}}-1}M_{\text{bit}}^{(i)}$ of the scrambled block of bits matches the amount of resource-element groups not assigned to PCFICH or PHICH.

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>

6.8.5 Mapping to resource elements

The mapping to resource elements is defined by operations on quadruplets of complex-valued symbols. Let $z^{(p)}(i) = \left\langle y^{(p)}(4i), y^{(p)}(4i+1), y^{(p)}(4i+2), y^{(p)}(4i+3) \right\rangle$ denote symbol quadruplet i for antenna port p.

The block of quadruplets $z^{(p)}(0),...,z^{(p)}(M_{\text{quad}}-1)$, where $M_{\text{quad}} = M_{\text{symb}}/4$, shall be permuted resulting in $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$. The permutation shall be according to the sub-block interleaver in Section 5.1.4.2.1 of [3] with the following exceptions:

- the input and output to the interleaver is defined by symbol quadruplets instead of bits
- interleaving is performed on symbol quadruplets instead of bits by substituting the terms 'bit', 'bits' and 'bit sequence' in Section 5.1.4.2.1 of [3] by 'symbol quadruplet', 'symbol quadruplets' and 'symbol-quadruplet sequence', respectively

<NULL> elements at the output of the interleaver in [3] shall be removed when forming $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$. Note that the removal of <NULL> elements does not affect any <NIL> elements inserted in Section 6.8.2.

The block of quadruplets $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$ shall be cyclically shifted, resulting in $\overline{w}^{(p)}(0),...,\overline{w}^{(p)}(M_{\text{quad}}-1)$ where $\overline{w}^{(p)}(i) = w^{(p)}\left((i + N_{\text{ID}}^{\text{cell}}) \bmod M_{\text{quad}}\right)$.

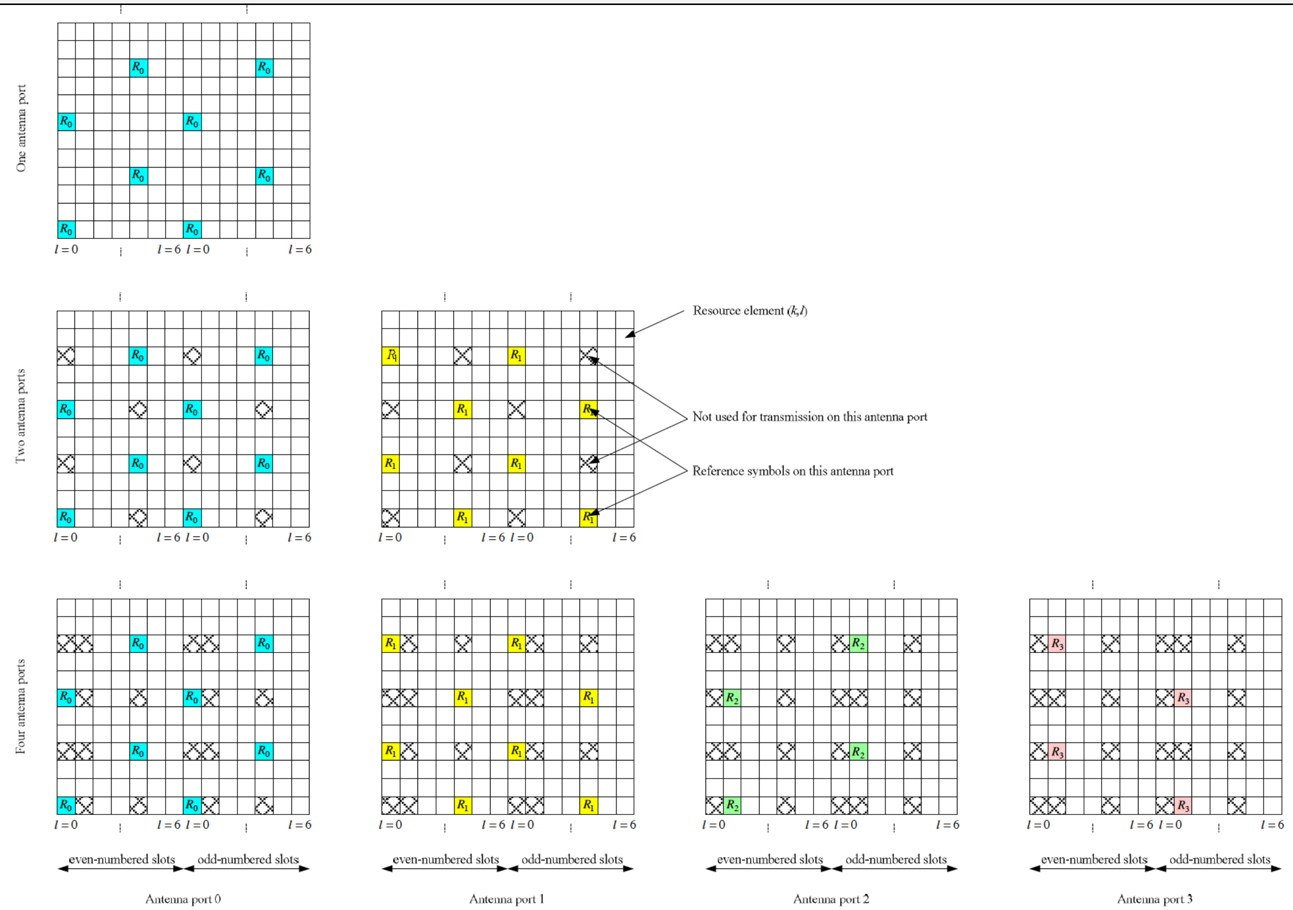
Mapping of the block of quadruplets $\overline{w}^{(p)}(0),...,\overline{w}^{(p)}(M_{\text{quad}}-1)$ is defined in terms of resource-element groups, specified in Section 6.2.4, according to steps 1–10 below:

1) Initialize $m' = 0$ (resource-element group number)
2) Initialize $k' = 0$

</td></tr>
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	3) Initialize $l'=0$ 4) If the resource element (k',l') represents a resource-element group and the resource-element group is not assigned to PCFICH or PHICH then perform step 5 and 6, else go to step 7 5) Map symbol-quadruplet $\overline{w}^{(p)}(m')$ to the resource-element group represented by (k',l') for each antenna port p 6) Increase m' by 1 7) Increase l' by 1 8) Repeat from step 4 if $l'<L$, where L corresponds to the number of OFDM symbols used for PDCCH transmission as indicated by the sequence transmitted on the PCFICH 9) Increase k' by 1 10) Repeat from step 3 if $k'<N_{\mathrm{RB}}^{\mathrm{DL}} \cdot N_{\mathrm{sc}}^{\mathrm{RB}}$ Source: 3GPP TS 36.211 V10.7.0 at 67-69. **6.10 Reference signals** Five types of downlink reference signals are defined: - Cell-specific reference signals (CRS) - MBSFN reference signals - UE-specific reference signals (DM-RS) - Positioning reference signals (PRS) - CSI reference signals (CSI-RS) There is one reference signal transmitted per downlink antenna port.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	6.10.1.2 Mapping to resource elements Figures 6.10.1.2-1 and 6.10.1.2-2 illustrate the resource elements used for reference signal transmission according to the above definition. The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p .

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	 **Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix).**

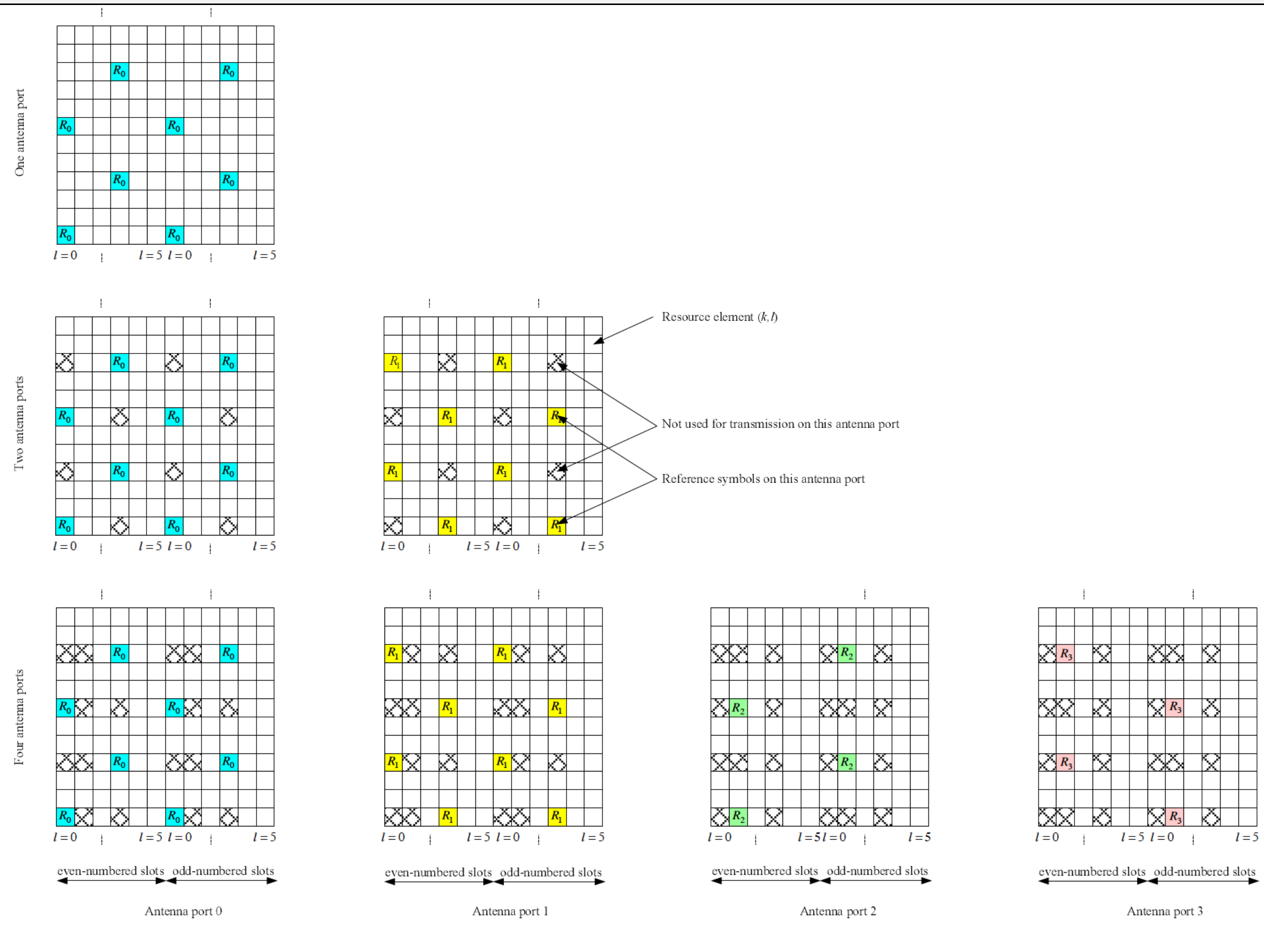
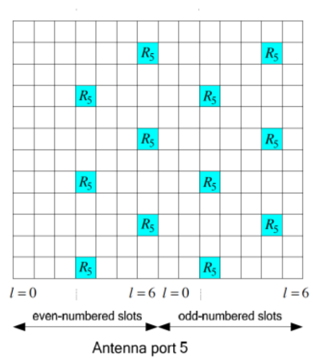
<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>

Figure 6.10.1.2-2. Mapping of downlink reference signals (extended cyclic prefix).</td></tr>
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	6.10.3 UE-specific reference signals UE-specific reference signals are supported for transmission of PDSCH and are transmitted on antenna port(s) $p=5$, $p=7$, $p=8$ or $p=7,8,...,\upsilon+6$, where υ is the number of layers used for transmission of the PDSCH. UE-specific reference signals are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to Section 7.1 of [4]. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped. The UE-specific reference signal is not transmitted in resource elements (k,l) in which one of the physical channels or physical signals other than UE-specific reference signal defined in 6.1 are transmitted using resource elements with the same index pair (k,l) regardless of their antenna port p. **6.10.3.2 Mapping to resource elements** For antenna port 5, in a physical resource block with frequency-domain index n_{PRB} assigned for the corresponding PDSCH transmission, the reference signal sequence $r_{n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p=5$ in a subframe according to:  **Figure 6.10.3.2-1: Mapping of UE-specific reference signals, antenna port 5 (normal cyclic prefix).**

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>

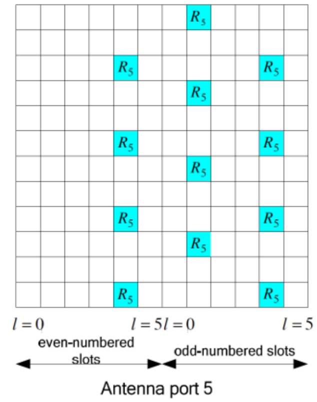


Figure 6.10.3.2-2: Mapping of UE-specific reference signals, antenna port 5 (extended cyclic prefix).

Source: 3GPP TS 36.211 V10.7.0 at 73-82.

7.2.2 SOUNDING REFERENCE SIGNALS

The DM-RS discussed in Section 7.2.1 are intended to be used by the base station for channel estimation to allow for coherent demodulation of uplink physical channels (PUSCH or PUCCH). A DM-RS is always transmitted together with and spanning the same frequency range as the corresponding physical channel.

In contrast, SRS are transmitted on the uplink to allow for the base station to estimate the uplink *channel state* at different frequencies. The channel-state estimates can then, for example, be used by the base-station scheduler to assign resource blocks of instantaneously good quality for uplink PUSCH transmission from the specific device (uplink channel-dependent scheduling). They can also be used to select different transmission parameters

Source: "4G, LTE-Advanced Pro and The Road to 5G," (Academic Press 3d Ed. 2016) at 185.

PDCCH is transmitted in the first symbols of a first time slot of a subframe, where a physical downlink shared channel is transmitted in the remaining symbols of the first slot and in a second slot of the subframe.

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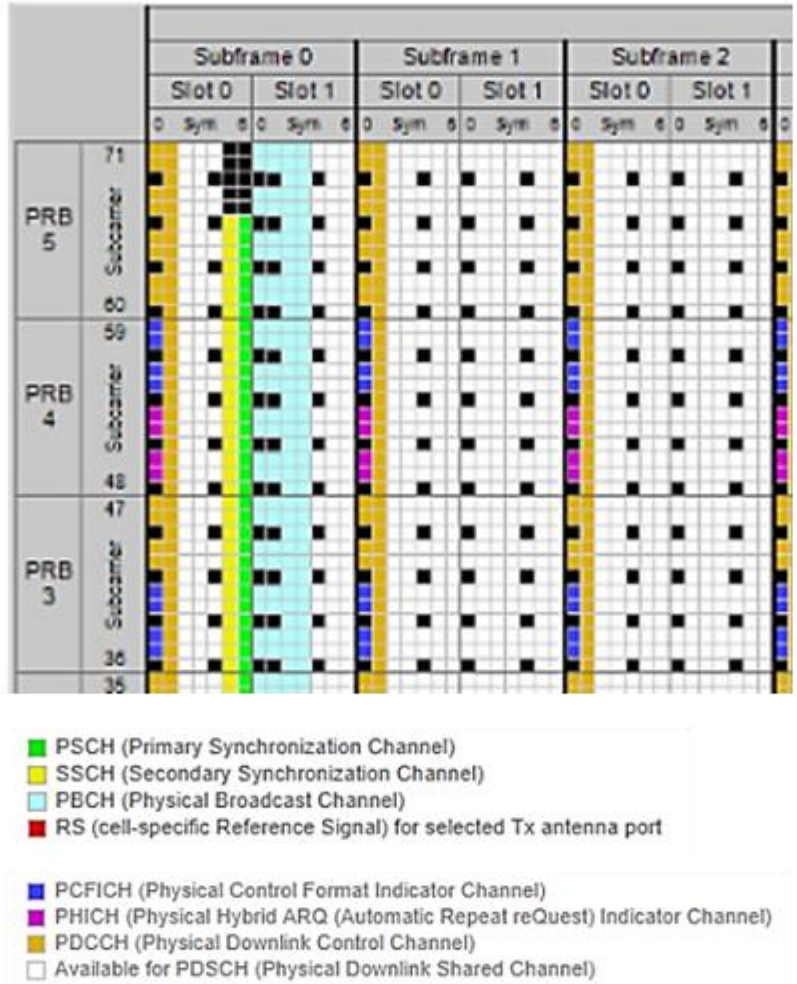
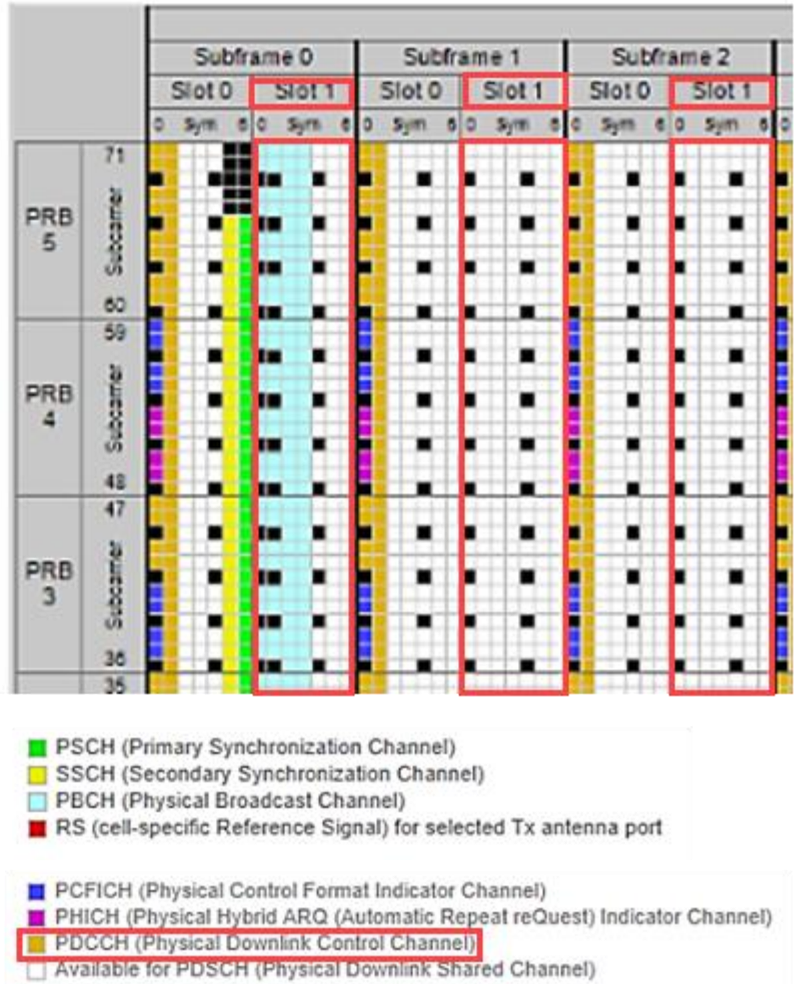
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	 Source: https://www.sharetechnote.com/html/FrameStructure_DL.html. The second slot of each downlink subframe does not include PDCCH.

<table>
<tr><th colspan="2">U.S. Patent No. 11,032,000 (Claim 1)</th></tr>
<tr><th>Claim 1</th><th>Example American Count IV Systems and Services</th></tr>
<tr><td></td><td>


Source: https://www.sharetechnote.com/html/FrameStructure_DL.html.

DCI Format 0 contains different fields and a different number of bits (45 bits in this example) than DCI Format 4 (53 bits in this example).
</td></tr>
</table>

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	(continued below)

6.4.3 **PHYSICAL DOWNLINK CONTROL CHANNEL**

The PDCCH is used to carry downlink control information (DCI) such as scheduling decisions and power-control commands. More specifically, the DCI can include:

Table 6.4 DCI Formats

	DCI Format	Example Size (Bits)	Usage
Uplink	0	45	Uplink scheduling grant
	4	53	Uplink scheduling grant with spatial multiplexing
	6-0A, 6-0B	46, 36	Uplink scheduling grant for eMTC devices (see Chapter 20)
Downlink	1C	31	Special purpose compact assignment
	1A	45	Contiguous allocations only
	1B	46	Codebook-based beam-forming using CRS
	1D	46	MU-MIMO using CRS
	1	55	Flexible allocations
	2A	64	Open-loop spatial multiplexing using CRS
	2B	64	Dual-layer transmission using DM-RS (TM8)
	2C	66	Multi-layer transmission using DM-RS (TM9)
	2D	68	Multi-layer transmission using DM-RS (TM10)
	2	67	Closed-loop spatial multiplexing using CRS
	6-1A, 6-1B	46, 36	Downlink scheduling grants for eMTC devices (see Chapter 20)
Special	3, 3A	45	Power control commands
	5		Sidelink operation (see Chapter 21)
	6-2		Paging/direct indication for eMTC devices (see Chapter 20)

Source: "4G, LTE-Advanced Pro and The Road to 5G," (Academic Press 3d Ed. 2016) at 138.

The number of bits sent over the PDCCH depends on the number of fields in the DCI. In the example of FDD single-carrier with SRS request and 100 RBs, the DCI Format 0 message includes the fields shown and 45 bits.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	5.3.3.1.1 Format 0 DCI format 0 is used for the scheduling of PUSCH in one UL cell. The following information is transmitted by means of the DCI format 0: - Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A - Frequency hopping flag – 1 bit as defined in section 8.4 of [3]. This field is used as the MSB of the corresponding resource allocation field for resource allocation type 1. - Resource block assignment and hopping resource allocation – $\left\lceil \log_2(N_{RB}^{UL}(N_{RB}^{UL}+1)/2) \right\rceil$ bits - Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3] - New data indicator – 1 bit - TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3] - Cyclic shift for DM RS and OCC index – 3 bits as defined in section 5.5.2.1.1 of [2] - CSI request – 1 or 2 bits as defined in section 7.2.1 of [3]. The 2-bit field applies to UEs that are configured with more than one DL cell and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3]; otherwise the 1-bit field applies - SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PUSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3] - Resource allocation type – 1 bit. This field is only present if $N_{RB}^{UL} \le N_{RB}^{DL}$. The interpretation of this field is provided in section 8.1 of [3] Source: 3GPP TS 36.212 V10.9.0 at 57-58. For the same example of FDD single-carrier with 100 RBs, DCI Format 4 includes the shown fields and 53 bits.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**
	5.3.3.1.8 Format 4 DCI format 4 is used for the scheduling of PUSCH in one UL cell with multi-antenna port transmission mode. The following information is transmitted by means of the DCI format 4: - Resource block assignment - $\max\left(\left\lceil \log_2(N_{RB}^{UL}(N_{RB}^{UL}+1)/2)\right\rceil, \left\lceil \log_2\left(\binom{\lceil N_{RB}^{UL}/P+1\rceil}{4}\right)\right\rceil\right)$ bits, where P is the UL RBG size as defined in section 8.1.2 of [3] - TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3] - Cyclic shift for DM RS and OCC index – 3 bits as defined in section 5.5.2.1.1 of [2] - CSI request – 1 or 2 bits as defined in section 7.2.1 of [3]. The 2-bit field applies to UEs that are configured with more than one DL cell; otherwise the 1-bit field applies - SRS request – 2 bits as defined in section 8.2 of [3] - Resource allocation type – 1 bit as defined in section 8.1 of [3] In addition, for transport block 1: - Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3] - New data indicator – 1 bit In addition, for transport block 2: - Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3] - New data indicator – 1 bit Precoding information and number of layers: number of bits as specified in Table 5.3.3.1.8-1. Bit field as shown in Table 5.3.3.1.8-2 and Table 5.3.3.1.8- 3. Note that TPMI for 2 antenna ports indicates which codebook index is to be used in Table 5.3.3A.2-1 of [2], and TPMI for 4 antenna ports indicates which codebook index is to be used in Table 5.3.3A.2-2, Table 5.3.3A.2-3, Table 5.3.3A.2-4 and Table 5.3.3A.2-5 of [2]. If both transport blocks are enabled, transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1. In case one of the transport blocks is disabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For a single enabled codeword, indices 24 to 39 in Table 5.3.3.1.8-3 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers. Source: 3GPP TS 36.212 V10.9.0 at 72-73. For the same example of FDD single-carrier with 100 RBs, DCI Format 4 includes the shown fields and 53 bits.

U.S. Patent No. 11,032,000 (Claim 1)	
Claim 1	**Example American Count IV Systems and Services**

Table 5.3.3.1.8-1: Number of bits for precoding information

Number of antenna ports at UE	Number of bits for precoding information
2	3
4	6

Table 5.3.3.1.8-2: Content of precoding information field for 2 antenna ports

One codeword: Codeword 0 enabled Codeword 1 disabled		Two codewords: Codeword 0 enabled Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	1 layer: TPMI=0	0	2 layers: TPMI=0
1	1 layer: TPMI=1	1-7	reserved
2	1 layer: TPMI=2		
...	...		
5	1 layer: TPMI=5		
6-7	reserved		

Table 5.3.3.1.8-3: Content of precoding information field for 4 antenna ports

One codeword: Codeword 0 enabled Codeword 1 disabled		Two codewords: Codeword 0 enabled Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	1 layer: TPMI=0	0	2 layers: TPMI=0
1	1 layer: TPMI=1	1	2 layers: TPMI=1
...	...	...	...
23	1 layer: TPMI=23	15	2 layers: TPMI=15
24	2 layers: TPMI=0	16	3 layers: TPMI=0
25	2 layers: TPMI=1	17	3 layers: TPMI=1
...	...	...	...
39	2 layers: TPMI=15	27	3 layers: TPMI=11
40-63	reserved	28	4 layers: TPMI=0
		29 - 63	Reserved

Source: 3GPP TS 36.212 V10.9.0 at 72-73.